# Demo: Enabling AGILE Spectrum Adaptation in Commercial 802.11 WLAN Deployments

Stratos Keranidis[⊕], Kostas Chounos[⊕], Thanasis Korakis[⊕],
Iordanis Koutsopoulos[⊎] and Leandros Tassiulas[⊕]
[○]Department of Computer and Communication Engineering, University of Thessaly, Greece
[+]Centre for Research and Technology Hellas, CERTH, Greece
[∪]Department of Computer Science, Athens University of Economics and Business, Greece
{efkerani, hounos, korakis, leandros}@uth.gr, jordan@aueb.gr

## ABSTRACT

In this work, we present the AGILE Spectrum Adaptation system that is able to dynamically tune the channel central frequency and bandwidth of wireless links in an adaptive to the interference and traffic conditions way. The developed system is able to detect under-utilised spectrum fragments and optimally adjust the occupied spectrum. Through the online execution of 3 specifically designed experimental scenarios, we demonstrate the ability to implement distributed spectrum adaptation in commercial WLAN deployments, along with the obtained performance benefits.

## 1. INTRODUCTION

The unlicensed part of the wireless spectrum is currently experiencing unprecedented levels of congestion, especially in densely populated urban areas. The resulting spectrum scarcity mainly results due to the tremendous growth of IEEE 802.11 WLAN deployments. Towards avoiding heavily utilised spectrum fragments and improving throughput performance, a large body of work [1, 2, 3, 4] has proposed approaches that dynamically tune the operating channel, by considering the prevailing interference and traffic conditions. Moreover, due to the fact that the ISM band is also home for other wireless protocols and a large range of RF devices, cross-technology interference is considered as a major performance degradation factor for 802.11 networks as well. Towards identifying non-802.11 devices, the work of [5] implemented a signal classification framework on top of commercial 802.11 hardware that makes use of detailed spectral scanning information. While identification of the unique type of RF device that generates performance anomalies was enabled, interference mitigation through proper spectrum adaptation was not addressed in this work.

The lack of interference-free channels has recently led researchers to the development of more sophisticated spectrum adaptation mechanisms that use channels of arbitrarily configured central frequency and bandwidth. Such mechanisms are to able to provide for versatile spectrum adaptation and hence improve spectrum efficiency, which is considered as a major goal in the field of dynamic spectrum access. In this context, several innovative schemes [6, 7] have been proposed and implemented on custom built research prototypes, clearly showcasing the benefits that agile spectrum adaptation is able to offer. The limitation of the aforementioned approaches is that they are not compatible with the 802.11 protocol, hence not offering for direct performance comparison with the standard. On the other hand, the work in [8] was the first to implement flexible channellisation on enterprise 802.11 networks, through the introduction of a central controller entity that is used to adapt spectrum configurations per link and resolve potential conflicts, which exacerbate due to the use of varying channel widths. However, the adopted centralised architecture that is not consistent with the distributed operation of the 802.11 protocol consisted the proposed approach non-applicable to common uncoordinated WLAN deployments.

In this work, we present AGILE - an approach to adapt the occupied spectrum based on distributed decisions that are taken locally at the AP. Efficient detection of transmissions that utilise different bandwidth configurations and identification of potential link conflicts is based on the collection of spectral occupancy information that is derived from the commercial 802.11n compatible Atheros AR9380 wireless chipset. Following this generic approach, we are able to characterise the Power Spectral Density (PSD) and Duty Cycle (DC) of active transmissions per frequency and thus efficiently identify heavily-utilised spectrum fragments that are occupied by any type of RF transmissions (even non-802.11). The developed scheme is not restricted by the standard channellisation and is able to appropriately configure the central frequency of operation at the granularity of 1 MHz. Towards increasing spectrum efficiency, channel bandwidth is also adapted among the 4 supported by the standard channel widths (40 MHz, 20 MHz, 10 MHz and 5 MHz), in order to constantly utilise the minimum required bandwidth that is able to meet the application-layer traffic requirements. Associated stations are informed about updated spectrum parameters through information that is embedded in *Beacon* frames and reconfiguration is able to take place per each *Beacon* interval. As collection of spectral information and subsequent spectrum adaptation induce only minimal overhead, the entire procedure runs in parallel with normal network operation and is totally transparent to higher protocol layers. To the best of our knowl-

*MobiCom'14,* September 7-11, 2014, Maui, Hawaii, USA.
ACM 978-1-4503-2783-1/14/09.
http://dx.doi.org/10.1145/2639108.2641752 .

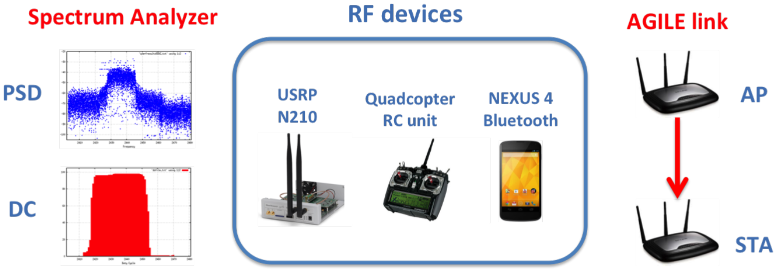
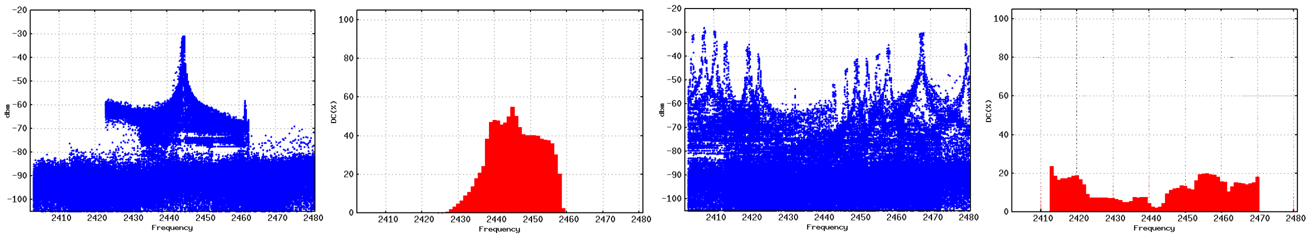


**Figure 1: Experimental Topology in Scenario 1.**



(a) Microwave oven PSD (b) Microwave oven DC (c) Quadcopter R/C PSD (d) Quadcopter R/C DC

**Figure 2: Power Spectral Density and Duty Cycle characterization of varying type RF transmissions.**

edge, AGILE is the first driver level implementation of fully distributed spectrum adaptation in commercial WLAN deployments that is also built on top of the high-throughput 802.11n protocol version.

In this demonstration, we will showcase three different experimental scenarios that clearly demonstrate the advantages of AGILE spectrum adaptation in commercial 802.11 WLAN deployments.

## 2. EXPERIMENTAL DEMONSTRATION

In Scenario 1, we demonstrate the ability of AGILE to detect non-802.11 RF devices, while Scenario 2 is designed to showcase the increased throughput performance that bandwidth reduction is able to offer under high-interference conditions. Finally, in Scenario 3 we show how AGILE is able to tune the operational bandwidth in order to meet the application-layer traffic requirements. In all experiments, we will use one PC as a Spectrum Analyzer that is built on top of the commercial AR9380 chipset to represent the PSD and DC evaluation of the entire band under consideration every 500 ms. Moreover, the AGILE mechanisms will be running on commercial TP-Link routers that feature the AR9380 chipset, in order to demonstrate the straightforward applicability of the developed framework in commercial off-the-self devices.

### 2.1 Scenario 1

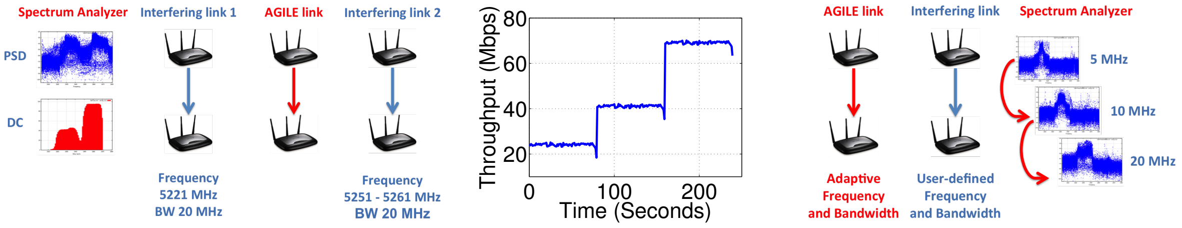
In this scenario, we use several RF devices that operate in the 2.4 GHz band and show how AGILE is able to detect ongoing non-802.11 transmissions and appropriately tune the central frequency to operate on the least utilised part of the spectrum. The experimental topology is depicted in Fig. 1. More specifically, we use the Software-defined Radio USRP N210 to emulate the operation of a microwave oven that occupies several channels of the 2.4 GHz band with the duty cycle of 50% and a wireless camera that uses a bandwidth of 18 MHz and duty cycle of 100%. In addition, we will also employ two frequency hopping devices, a Quadcopter R/C unit that transmits at the high power of 27 dBm and a Bluetooth 4.0 transceiver of LG Nexus 4 that transmits at 10 mW. Indicative PSD plots that will be showcased during the demonstration are presented in Fig. 2(a) and Fig. 2(c), while the detected DC is depicted in Fig. 2(b) and Fig 2(d) accordingly.

### 2.2 Scenario 2

In Scenario 2, we aim at demonstrating the ability of AGILE to adapt under rich in interference environments and configure the experimental topology that is depicted in Fig. 3(a). To this end, we establish two wireless links on the 5 GHz band that occupy 20 MHz of bandwidth and use them as potential interferers for a third link that implements the proposed mechanism. In the first phase, the two interfering links operate on frequencies 5221 MHz and 5251 MHz accordingly, leaving a part of 10 MHz spectrum space unoccupied. In the second phase, we switch the central frequency of the second interfering link by 10 MHz and assign the central frequency of 5261 MHz, resulting in 20 MHz of unoccupied spectrum. The AGILE-enabled link will be dynamically configuring the optimal frequency and bandwidth parameters, towards improving throughput performance that will also be depicted in parallel with the experiment execution.

### 2.3 Scenario 3

Finally, in Scenario 3 we will establish a link that features varying application-layer traffic requirements and showcase how AGILE is able to tune the operational bandwidth in order to successfully meet the traffic demands that vary over time, as illustrated in Fig. 3(b). In this scenario, demo spectators will also have the ability to interact with the system by tuning the central frequency and bandwidth of an interfering link through a user friendly interface and observe how AGILE adapts to the resulting environment. The experimental topology of this scenario is presented in Fig. 3(c).



(a) Scenario 2 - Topology (b) Scenario 3 - Traffic demand (c) Scenario 3 - Topology

**Figure 3: Experimental configuration in Scenarios 2 and 3.**

## 3. DEMO REQUIREMENTS

For the purposes of this demonstration, we will bring:

- our projector and laptops
- 6 wireless Routers, 1 wireless node to operate as the Spectrum Analyzer and the 3 RF devices that will be used in Scenario 2,

while we will also require:

- a desk of 2 meters length to place the equipment,
- power supply for all the devices.
- 30 minutes for setup and testing.

## 4. CONCLUSIONS

In this demo paper we showcase the AGILE system that implements Spectrum Adaptation in commercial 802.11 devices. The implemented approach operates as a spectrum occupancy detector that appropriately configures the link to operate on the spectrum fragment that features the lowest Duty Cycle. As revealed through the three different demonstrated scenarios, the implemented mechanism is able to dynamically adapt to the prevailing channel and traffic conditions and offer significant improvement in comparison with conventional 802.11 systems.

## 5. ACKNOWLEDGEMENTS

The authors acknowledge the support of the European Commission through IP project CREW (FP7-258301).

## 6. REFERENCES

[1] A. Mishra, V. Shrivastava, D. Agrawal, S. Banerjee, and S. Ganguly. Distributed Channel Management in Uncoordinated Wireless Environments. In *Proceedings of MOBICOM*, 2006.

[2] B. Kauffmann, F. Baccelli, A. Chaintreau, V. Mhatre, K. Papagiannaki, and C. Diot. Measurement-Based Self Organization of Interfering 802.11 Wireless Access Networks. In *Proceedings of INFOCOM*, 2007.

[3] S. Chieochan, E. Hossain, and J. Diamond. Channel assignment schemes for infrastructure-based 802.11 WLANs: A survey. *Communications Surveys Tutorials, IEEE*, 2010.

[4] G. Kazdaridis, S. Keranidis, A. Fiamegkos, T. Korakis, I. Koutsopoulos, and L. Tassiulas. Novel Metrics and Experimentation Insights for Dynamic Frequency Selection in Wireless LANs. In *Proceedings of ACM WiNTECH*, 2011.

[5] Shravan Rayanchu, Ashish Patro, and Suman Banerjee. Airshark: Detecting non-WiFi RF Devices Using Commodity WiFi Hardware. In *Proceedings of IMC*, 2011.

[6] Krishna C., Bozidar R., Vlad B., Michael B., Srinivas Yerramalli, Vishnu Navda, and Ramachandran Ramjee. WiFi-NC : WiFi Over Narrow Channels. In *Proceedings of NSDI*, 2012.

[7] S. Yun, D. Kim, and L. Qiu. Fine-grained Spectrum Adaptation in WiFi Networks. In *Proceedings of MOBICOM*, 2013.

[8] S. Rayanchu, V. Shrivastava, S. Banerjee, and R. Chandra. FLUID: Improving Throughputs in Enterprise Wireless Lans Through Flexible Channelization. In *Proceedings of MOBICOM*, 2011.